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CHRONIC LOW BACK PAIN IN YOUNG ADULT MALES*

PRELIMINARY REPORT

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CHRONIC low back pain is a common disability in young adults. One-sixth of the patients at present under treatment at this centre are suffering from the condition. Its diagnosis and treatment constitute perhaps the most complex problem in clinical medicine. It is, however, essential that a pathological diagnosis be made wherever possible, so that correct treatment can be applied. The purpose of the study here described was to determine the diagnosis in cases of chronic low back pain and to assess the relative values of investigation in reaching that diagnosis. No attempt is made to discuss the effects of treatment.

The present series consists of 75 consecutive cases of chronic low back pain in males aged between 18 and 50 admitted to the Royal Air Force Medical Rehabilitation Unit, Chessington, between June 1, 1952, and March 15, 1953. The criterion for selection of patients was that they had required either treatment or modification of their normal activities for a period of three months or more. The majority were admitted direct from hospital for full-time rehabilitation. There had, therefore, been some prior selection of patients, so that cases of infectious diseases of the spine and of urinary disease causing backache were unlikely to have been included.

Method of Investigation

The examination of patients closely followed the method adopted by Armstrong (1952) in his analysis of cases of lumbar disk lesions, and con-

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sists of careful history-taking, clinical examination, and accessory methods of investigation. The findings were recorded on a standard proforma.

1. *History*.—As a detailed history is so important, the patient was first encouraged to tell his story in his own time. A number of leading questions were then asked. The examiner used the proforma not only to guide his questioning, but also to put additional questions which might arise out of the patient's answer. Close attention was paid to a history of trauma in early childhood (in view of a possible relationship to pars interarticularis defects), the relationship of any urinary or rectal symptoms to backache, and the effect of the patient's trouble on his work and on playing games with particular reference to fatigue.

2. *Clinical Examination*.—A full clinical examination of all systems was made, including measurement of chest expansion. The circumference of the thigh 5 inches (12.7 cm.) above the upper border of the patella and the maximum calf circumference were measured, in each case the difference between the two limbs being recorded.

3. *Accessory Methods of Diagnosis*.—These included estimation of the erythrocyte sedimentation rate (E.S.R.) and full urine analysis. Radiographs were taken as a routine in the antero-posterior, lateral, and oblique positions of the lumbar spine and the anterior and oblique positions of the sacro-iliac joints, with the addition of other regions as indicated clinically.

Results

CLASSIFICATION

The various pathological conditions discovered have been classified into seven main groups (see Table I). Multiple pathology has been surprisingly frequent and has made classification difficult. In one-third of the patients another condition apart from the main diagnosis was found, but, in general, patients have been grouped under the major pathological finding. Several patients complaining of pain in the lumbar region were found to be suffering from Scheuermann's disease (in both the active and the inactive stage). To enable this relationship to be studied, cases of Scheuermann's disease have been grouped together.

Patients suffering from disk protrusion have been classified into two groups according to the limitation of straight leg raising (*a*) below 40 degrees and (*b*) between 40 and 60 degrees. There were, however, no marked differences in onset, clinical course, or signs in the two groups. Even so, it was felt that, in view of the differences in operative findings (Charnley, 1951), results of treatment should be assessed separately. Each of the three major groups presented definite characteristic features.

Prolapsed Intervertebral Disk

(*a*) *Onset*.—Pain was first felt in the lumbar region in 69%, in the sciatic distribution in 28%, and in both in 3%. There was a history of direct injury, jarring, or flexion strain of the spine immediately before the

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TABLE I

CLASSIFICATION OF PATIENTS SUFFERING FROM LOW BACK PAIN ACCORDING TO PATHOLOGICAL DIAGNOSIS

Pathology	No. of Patients Studied in Group	No. of Patients with Additional Pathology	Age Group (years)	Average Age (years)
1. Prolapsed intervertebral disk with straight leg raising below 40 degrees	23	—	18-50	23.75
With bilateral crack of pars interarticularis of L5 vertebra	1	(1)		
With spondylolysis of L3 vertebra	—	1		
With spondylolysis of L5 vertebra	—	1		
With spondylolisthesis of L5 vertebra	—	1		
With Scheuermann's disease	—	3		
Total	30			
2. Prolapsed intervertebral disk with straight leg raising between 40 and 60 degrees	8	—	18-31	22.4
3. Transitional changes at lumbo-sacral junction ..	4	—	18-23	20.0
4. Spondylolysis	3	—	18-23	20.5
Spondylolisthesis	2	—		
Fracture of pars interarticularis of L2 vertebra	(1)	1		
Spondylolysis and spondylolisthesis with prolapsed intervertebral disk	(3)	3		
Incidental finding	—	5		
Total	14			
5. Scheuermann's disease	6	(4)	17-26	21.2
With spondylolysis of L5	—	1		
With ankylosing spondylitis	—	1		
Total	8			
6. Ankylosing spondylitis	12	(2)	18-32	22.9
7. Miscellaneous	12	—	18-47	23.92
TOTAL	75	24		

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onset of symptoms in 73% of cases. In 44% pain followed immediately upon trauma or, in the absence of trauma, became severe within a few hours; in 56% there was a gradual onset of dull aching pain in the lumbar region or in the sciatic distribution over several days or weeks; 62% of patients described their pain as acute, sharp, or stabbing, and the remainder as a dull ache, burning, or stinging.

(b) *Course*.—In the majority of patients acute pain subsided after a few days, but a residual ache persisted for several months. Chronic backache tended to be punctuated by attacks of acute pain, particularly if the patient tried to become more active. The back rarely felt stiff unless there were acute pain and muscle spasm.

(c) *Findings*.—The more important diagnostic features were:

1. Flattening of lumbar lordosis or lumbar kyphosis (78%).
2. Pain on coughing, sneezing, walking, or prolonged sitting.
3. Marked scoliosis in the lumbar region in the presence of muscle spasm (62%).
4. Pain and limitation of flexion and hyperextension in the presence of pain-free lateral movements. Pain on hyperextension was present in 41% of cases, and in several was of such severity that modification of hyperextension exercises was required.
5. Tenderness of lower lumbar spine (65%) or sacro-iliac joints (9%).
6. Neurological signs indicative of a root lesion (84%).
7. Limitation of straight leg raising test below 60 degrees closely correlated with the degree of limitation of forward flexion.

(d) *Radiological Examination*.—This was of little value in demonstrating the occurrence of a disk lesion. Narrowing of the L4/5 disk space was found in one patient. Narrowing of the L5/S1 disk space was more frequent, but in the age group concerned in this study narrowing resulting from a protruded disk often cannot be distinguished from congenital narrowing.

Spondylolysis and Spondylolisthesis

This group consists of 9 patients between the ages of 18 and 23. In addition, spondylolysis was considered to be an incidental finding in 5 patients included in other diagnostic groups. The situation of the lesion and the nature of additional pathology are detailed in Table II. In no case was there evidence of trauma at any time during childhood. Three patients in whom there was strong evidence of disk protrusion and one patient suffering from crush fracture of the 2nd lumbar vertebra were excluded from study. The history and clinical features in the remaining 2 patients with spondylolisthesis and 3 patients with spondylolysis were very similar.

(a) *Onset*.—This may be rapid or gradual. In 2 patients symptoms followed a fall on the lumbar spine. In all patients the pain was situated in the lower lumbar region; in some it radiated into one or both groins, and in others into the buttocks.

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TABLE II

SITUATION OF LESIONS IN PATIENTS SUFFERING FROM SPONDYLOLYSIS AND SPONDYLOLISTHESIS AND NATURE OF ADDITIONAL PATHOLOGY

Case No.	Site of Lesions of Pars Interarticularis	Age (years)	Nature of Additional Pathology
<i>Spondylolysis and Spondylolisthesis Group</i>			
1	3rd lumbar, bilateral	20	Lesion of 3rd lumbar nerve root clinically due probably to protrusion of the L2/3 intervertebral disk
2	5th lumbar, bilateral	18	Lesion of 5th lumbar nerve root clinically due probably to protrusion of L4/5 intervertebral disk. Partial sacralization of S1 and S2 vertebrae
3	5th lumbar, bilateral	19	Spondylolisthesis Grade I (Myerding, 1932). Blunting of inferior articular process of 4th lumbar vertebra
4	5th lumbar, bilateral	23	Splintering of left inferior articular process of 3rd lumbar vertebra. Blunting of left 5th lumbar inferior articular process
5	5th lumbar, bilateral	23	Spondylolisthesis Grade I (Myerding). Flattening of S1 superior articular process. Tip of right 3rd lumbar inferior articular process seen as separate ossicle displaced into joint space; probable old fracture
6	5th lumbar, bilateral	20	Spondylolisthesis Grade II (Myerding). Bilateral sciatica and limitation of straight leg raising below 40 degrees probably due to prolapsed intervertebral disk. Disseminated sclerosis
7	5th lumbar, right	18	Elongation of left pars interarticularis. Bilateral blunting of 4th lumbar inferior articular processes. Scheuermann's disease
8	5th lumbar, bilateral	23	
9	2nd lumbar, bilateral	21	Crush fracture of body of 2nd lumbar vertebra
<i>Scheuermann's Disease Group</i>			
10	5th lumbar, bilateral	17	Symptoms confined to thoracic region
<i>Lumbar Epiphysitis Group</i>			
11	5th lumbar, left	20	Elongation of right pars interarticularis
<i>Prolapsed Intervertebral Disk Group</i>			
12	5th lumbar, bilateral	50	(Hairline crack defect)
<i>Ankylosing Spondylitis Group</i>			
13	5th lumbar, right	18	(Hairline crack defect)
14	5th lumbar, bilateral	28	Blunting of inferior articular process of 4th lumbar vertebra both sides. Schmorl's nodes, T11-L4 vertebrae

(b) *Course*.—Pain was closely related to activity, and was described as an ache on standing, after exercise, or at the end of the day. Patients were sometimes aware of weakness or grating in the back and became afraid of excessive activity. They felt well apart from their back symptoms, and some had considerable pain-free periods, but pain might be severe one day and absent the next. In 3 patients pain arose or became worse while lying in bed.

(c) *Findings*.—These were as follows:

1. Pain came on at the extreme of spinal movements—on flexion in all patients and on extension or lateral movement in 3.

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2. The range of movement was not restricted.
3. Pain was not affected by coughing or sneezing.
4. Slight muscle spasm was present in 2 patients, and in another it could be produced by percussion of the 5th lumbar spinous process.
5. The spinous process of the affected vertebra was tender on palpation (4 cases).
6. Lumbar lordosis was increased (4).
7. Tenderness on palpating or springing the sacro-iliac joints occurred in 3 patients.
8. No neurological signs were observed. The straight leg raising test was slightly limited in 2 patients, but the ankle-dorsiflexion test was always negative.

The history and clinical features were sufficiently constant to warrant a radiological examination specifically for a defect of the pars interarticularis. In the patient with a fracture of the pars interarticularis in addition to a crush fracture of the 2nd lumbar vertebra, and in one case of ankylosing spondylitis, history and clinical findings were similar to those in the spondylolysis group. In the remaining cases there was no evidence to suggest that any of the symptoms or signs could be attributed to spondylolysis.

X-ray examination revealed considerable variation in the appearance of the lesion. In some cases the classical picture of a clear-cut "dog collar" was seen, and in others there was apparent fragmentation of the pars interarticularis. Compression and thickening of the articular facets (most commonly the inferior articular process of the 4th lumbar vertebra) was seen in 5 out of the 7 cases in which the clinical features were closely associated with the defect. Irregularity and sclerosis of the posterior apophysial joints were more marked in these cases. Alterations in the appearance of the articular processes were very slight in the remaining 7 cases, in which the clinical features were more closely associated with other pathological conditions. The radiographs of the crush fracture of the body of the 2nd lumbar vertebra with bilateral fracture of the posterior neural arch through the pars interarticularis showed wide separation of the fragments (Plate I, Fig. 1). On one side the margins of the fracture were still clearly demarcated ten months after injury and there was little evidence of callus formation. Healing on the opposite side was more advanced. At this time the patient was suffering from slight aching in the lumbar region on forward flexion, but was otherwise symptom-free.

Ankylosing Spondylitis

The average duration of symptoms before admission was 2 years 4 months. The diagnosis had been made in 4 cases within a year of onset of symptoms, and in 9 within the first three years. In no fewer than 5 patients symptoms had been associated with a traumatic incident shortly before onset. Whether this should be regarded as a stress factor or merely an

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attempt by the patient to explain his symptoms is open to question. Frequency of micturition was present temporarily in one case.

(a) *Onset*.—Ankylosing spondylitis in its early stages may resemble any condition causing low back pain.

The first patient in this group presented the history and signs of a prolapsed intervertebral disk with nerve-root involvement. He responded well to conservative treatment with rest in bed and a plaster jacket, and it was not until two months later that recurrence of lumbar pain and limitation of movement of the right hip-joint led to further radiological examination and estimation of E.S.R. That this is not an isolated example of the difficulty of distinguishing this condition from a disk lesion is confirmed by Key (1951), who reports no fewer than 18 patients suffering from ankylosing spondylitis who had been operated upon for a disk lesion. In 2 other patients symptoms in the right hip and the lower dorsal-upper lumbar region led to the diagnosis of possible tuberculosis of the hip and adolescent kyphosis six and nineteen months respectively before typical radiological changes were seen in the sacro-iliac joints.

(b) *Course*.—The patient complains of aching pain and stiffness most frequently in the lumbar region, which is worse if he keeps in one position, such as lying in bed, remaining rigid in a plaster jacket, or sitting in a cinema, and which is relieved by movement. It is stiffness rather than pain which troubles the patient when he remains still. After morning stiffness has worn off he begins to feel tired, and if exercise is attempted it is fatigue and pain rather than stiffness which call a halt. He usually has to steer a careful course between insufficient exercise which makes him stiff and excessive exercise which gives him pain. Commonly a patient suffering from this condition may find it difficult or impossible to complete a full day's rehabilitation programme.

Symptoms varied from day to day, but it was unusual to find a patient who said a day had passed completely free from pain or stiffness. All patients in this group except one complained of general ill-health. In only one patient was there marked loss of weight.

(c) *Accessory Methods*.—The E.S.R. is frequently normal in the early stage of ankylosing spondylitis. This is particularly true in the very slowly progressive cases, in which a raised value might otherwise have brought suspicion on the patient's condition. Four patients in this group had an E.S.R. reading below 10 mm. in 1 hour (Westergren) in spite of repeated examination.

(d) *X-ray Findings*.—Confirmation of the diagnosis of ankylosing spondylitis depends on the radiological detection of changes in the sacro-iliac joints or posterior apophysial joints, or calcification of the spinal ligaments. There were well-marked changes in both sacro-iliac joints in all but one case. In this case the changes were very slight, but there was commencing calcification of the anterior common ligaments between the

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12th thoracic and 1st lumbar vertebrae. Commencing calcification of the spinal ligaments was observed in 4 patients, and definite changes were noted in the posterior apophysial joints in 4 patients (33%).

Oblique views of the lumbar spine may occasionally be of value in indicating involvement of the posterior apophysial joints. In one patient complaining of aching in the lower region for twenty months the E.S.R. remained normal over a period of eight months, and radiographs of the sacro-iliac joints had been interpreted as normal. Oblique views of the lumbar spine showed partial obliteration of the posterior apophysial joints of the L4/5 and L5/S1 articulations, particularly on the right, and changes suggestive of ankylosing spondylitis in the remaining lumbar apophysial articulations (Plate I, Fig. 2).

From the 12 cases in this series it is evident that the early diagnosis of ankylosing spondylitis may depend on the natural history and clinical findings. In 6 patients a history suggestive of ankylosing spondylitis had been obtained several months or years before radiological changes were discovered.

(e) *Clinical Findings*.—These were:

1. Flattening of the lumbar spine was present in 7 patients, normal curvature in 3, and increased lordosis in 2.
2. Movement of the lumbar spine was limited in all patients, but in several the limitation was minimal.
3. Spasm and tenderness of the lumbar or thoracic spine were fairly constant and were present in 10 patients, being definitely localized to the sacro-iliac joints in only 3.
4. Chest expansion was reduced to $1\frac{1}{2}$ inches (3.75 cm.) or less, although in 3 patients expansion was over $2\frac{1}{2}$ inches (6.35 cm.) in the presence of well-marked changes in the sacro-iliac joints.
5. Pain on springing the sacro-iliac joints.

In the early stages several of these findings were absent.

Transitional Changes at the Lumbo-sacral Junction and Enlarged Transverse Processes

Diagnosis was based on radiological findings of transitional changes at the lumbo-sacral junction. This group, consisting of 4 patients, was found to be too small for the clinical and radiological findings to be correlated.

Scheuermann's Disease

In 4 patients in this group pain was in the lumbar region, and in 3 of these there was evidence of a prolapsed intervertebral disk with straight leg raising below 40 degrees. One patient with lumbar pain responded well to postural correction. This was in marked contrast to the result of treatment in another patient whose symptoms of low back pain were considered to be due to unilateral spondylolysis of the 5th lumbar vertebra (Plate II, Figs. 1 and 2) and in whom postural correction led to considerable increase

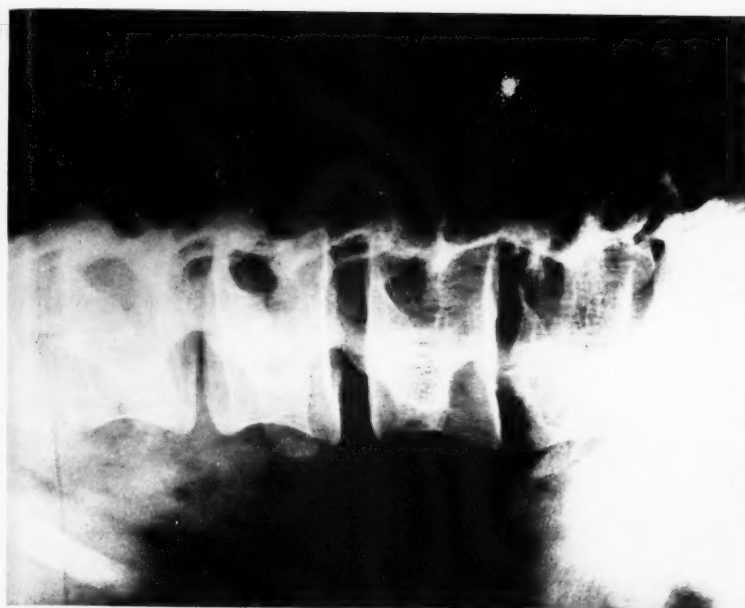


FIG. 2.—Ankylosing spondylitis. Left oblique view of lumbar spine showing early changes in apophysial joints with partial obliteration of joint spaces, and osseous bridge between superior articular process of 5th and inferior articular process of 4th lumbar vertebrae. The sacro-iliac joints were considered to be within normal limits.



FIG. 1.—Lateral radiograph showing compression fracture of 2nd lumbar vertebra, with break in posterior neural arch, ten months after injury. There was no forward dislocation.



FIG. 1.—Left oblique view in patient complaining of pain in lumbar region. The pars interarticularis of the 5th lumbar vertebra is intact but elongated. There is a blunting and compression of the inferior articular process of the 4th lumbar vertebra. Compare with inferior articular processes of 3rd and 5th lumbar vertebrae.



FIG. 2.—Same patient as Fig. 1. Right oblique view at 45 degrees. Blunting and compression of inferior articular process of 4th lumbar vertebra. A complete break in ossification of the pars interarticularis of the 5th lumbar vertebra was clearly demonstrated in a 30-degree oblique view with a 10-degree cephalic tilt.

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in pain. These differences must be taken into account when assessing the results of various forms of treatment.

Miscellaneous Cases

There were 12 patients in this group aged between 18 and 47, only 2 being over 30 years of age.

(i) *Lumbar Epiphysitis* (1 case).—This patient showed the clinical features of ankylosing spondylitis. On flexion the lumbar spine moved in one piece, but clinically and radiologically the sacro-iliac joints remained clear. A radiograph showed changes in the lumbar spine similar to those described by Kleinberg (1935).

(ii) *Protrusion of the Intervertebral Disk* between the 10th and 11th thoracic vertebrae—1 case.

(iii) *Psychogenic Muscle Pain* (1 case).—This patient showed localized spasm (a) of the erector spinae in various parts of the spine and (b) in the gluteal region, which might well have been described as fibrositis. His symptoms remained resistant to treatment elsewhere, which included heat and massage for nine months and an attempt at manipulation on osteopathic principles. Relief of his financial worries resulted in complete disappearance of all his symptoms and also the muscle spasm.

(iv) *Degenerated Disk Lesion* (1 case).—This patient (age 47) was the only one in which marked degenerative changes were found in the lumbo-sacral intervertebral disk joint with secondary changes in the posterior apophysial joints. Although symptoms had started with sudden lumbar pain, there were only slight neurological changes and the result of the straight leg raising test was normal.

(v) *Occupational Lumbar Lordosis* (1 case).—For some twelve years this patient had had to play a musical instrument weighing $\frac{1}{2}$ cwt., which he carried with his back arched. This was reflected radiologically in an extremely sharp lumbo-sacral angle.

(vi) *Postural and Post-traumatic Lumbar Pain with Psychological Overlay* (2 cases).—These 2 patients showed clear psychological overlay—associated with postural lumbar lordosis in one case and as a complication of trauma to the lumbar region in the other. Both complained bitterly of pain in spite of good function while performing exercises.

(vii) *Pathology Uncertain* (3 cases).—These cases gave a history with signs suggestive of an early disk lesion, but did not fulfil the criteria laid down in the earlier groups.

(viii) *Traumatic Ligamentous Lesion* (1 case).—This patient had been kicked in the lumbar region three months previously; his symptoms had persisted, but were completely relieved after a week's rehabilitation.

(ix) *Marked Thoraco-lumbar Scoliosis* (1 case).—This patient had a compensatory curve of the sacrum, symptoms being referred to the lumbo-sacral region.

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Previous Diagnosis

Earlier diagnoses are compared with the pathological diagnosis in each of the main groups in Table III. This table emphasizes the need for caution in the use of terms such as "fibrositis", "muscular rheumatism", "sacro-iliac strain", and "lumbo-sacral strain", which are frequently used to describe certain clinical findings. Before reaching a firm diagnosis an underlying pathological process should always be sought.

TABLE III
COMPARISON OF FINAL DIAGNOSIS WITH EARLIER DIAGNOSIS OF CHRONIC LOW BACK PAIN

<i>Ankylosing Spondylitis</i>				
Fibrositis	3	First lumbar ribs mistaken for fracture		
Lumbo-sacral strain	1	of transverse processes	1	
Synovitis of hip (Tb)	1	Myofascial syndrome	1	
Postural backache	1	Prolapsed intervertebral disk	1	
Osteitis condensans ilii	1	Scheuermann's disease	1	
Muscular rheumatism	1	Arthritis of spine	1	
<i>Spondylolysis and Spondylolisthesis</i>				
Lumbago	1	Loss of confidence	1	
Prolapsed disk	1	Sacro-iliac strain	1	
(No evidence for this)		Due to lying in bed	1	
<i>Prolapsed Intervertebral Disk</i>				
Sacro-iliac strain	3	Spondylolisthesis (not confirmed radio-		
Lumbo-sacral strain	2	logically)	2	
Lumbago and fibrositis	4	Postural backache	2	
Torn muscle	1	Nothing wrong	2	
<i>Lumbar Epiphysitis</i>				
Fibrositis	1			

Discussion and Conclusions

There were three major groups in this series. In 38 patients (50%) symptoms were considered to be due to a prolapsed intervertebral disk; in 12 (16%) there was radiological evidence of ankylosing spondylitis; and in 14 (18.6%) defects of the pars interarticularis were found. In 7 of the last group the similarity of clinical features suggested a direct association with a defect of the pars interarticularis, which included spondylolysis, spondylolisthesis, and fracture. In 5 of these patients there were compression and deformation of neighbouring articular processes. This feature was absent in the remaining 7, whose symptoms were considered to be due to some other cause. The incidence of this lesion as seen on anatomical and clinical examination is compared in Table IV. The higher incidence in patients suffering from low back pain underlines the fact that this lesion merits serious consideration as a cause of such pain. On the other hand, the lesion may be very stable and be highly resistant to trauma (Lachapelle and Lagarde, 1951). Frequency of micturition occurred in 2 of the 14 cases in which pars interarticularis defects were discovered. One of these patients was suffering from disseminated sclerosis. No rectal symptoms were

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TABLE IV

SUMMARY OF ANATOMICAL AND CLINICAL INVESTIGATION INTO INCIDENCE OF DEFECTS OF PARS INTERARTICULARIS

Author and Year	Type of Investigation	No. of Cases	No. in which Defects Found	Percentage of Defects
Roche and Rowe, 1951	Anatomical dissection of adult white males (ages 20-49)	699	47	6.7
Bailey, 1947	Radiological examination of unselected recruits	2,080	91	4.4
Rhodes and Colangelo, 1946	Routine radiological examination of lumbar region	1,000	21	2.1
Rhodes and Colangelo, 1946	Radiological examination for low back pain	250	39	15.6
Lerner and Gazin, 1946	Radiological examination for low back pain	511	52	10.1
Ghormley, 1951 ..	Radiological examination for backache and sciatic pain	2,000	57	2.9
Lachapelle and Lagarde, 1951	Radiological examination for lumbo-sacral pain and sciatica	2,000	10	0.5
Lachapelle and Lagarde, 1951	Radiological examination for lumbo-sacral pain and sciatica (lesion being looked for)	850	44	5.2
Present series	Radiological examination for chronic low back pain in young adult males	75	14	18.6

recorded in these patients. This is in contrast to a higher incidence in a slightly older age group reported by Roberts (1947).

In its early stages the diagnosis of ankylosing spondylitis depends on a study of the history and clinical features. A normal E.S.R. does not exclude ankylosing spondylitis, but a raised value is a useful confirmatory factor. Radiological changes in the sacro-iliac joints may be expected to occur eventually in 98% of cases (Polley and Slocumb, 1947). If the sacro-iliac joints are clear, changes may be seen in the posterior apophysial joints. Radiological changes, although conclusive, were a comparatively late feature in many cases in this series.

It is clear from this study that, if a definite pathological diagnosis cannot be made in a patient suffering from low back pain, it is essential that clinical investigation with the use of accessory methods should be repeated at frequent intervals. Chronic low back pain is often regarded by the general public as a normal feature of life. The medical profession is partly to blame for the widespread use of the terms "fibrositis" and "rheumatism". Several patients in this series had been lulled into considering that their symptoms were due to "rheumatism", and consequently visited their doctor only at a comparatively late stage. It is essential that physical

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methods of treatment should not be used as a palliative for "backache", but for the relief of a definite pathological process. This study has shown that it is possible to obtain a definite pathological diagnosis in the majority of cases of backache in young adults.

Summary

1. The relative values of history-taking, clinical examination, and accessory methods of investigation in reaching a diagnosis are compared in 75 cases of chronic low back pain in males aged between 18 and 50.

2. In 38 patients (50%) symptoms were considered to be due to a prolapsed intervertebral disk. Radiological confirmation of disk pathology was rarely obtained.

3. Twelve patients (16%) were found to be suffering from ankylosing spondylitis. In 3 patients a history suggestive of ankylosing spondylitis had been investigated two years before the lesion was confirmed radiologically. Partial obliteration of the posterior apophysial joints was seen radiologically in one patient at a time when the sacro-iliac joints appeared clear.

4. Defects of the pars interarticularis were found in 14 patients (18.6%). In 7 of these similar natural history and clinical findings were found and alteration in structure of the articular processes was seen radiologically. In the remainder symptoms were considered to be due to some other condition and the structure of the articular processes appeared intact.

5. A case of lumbar epiphysitis is described.

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THE MANAGEMENT OF PARKINSON'S DISEASE

A PRELIMINARY REPORT

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It has been recognized that short periods of remedial exercises two or three times a week produce some improvement of function in many cases of paralysis agitans. More recently Voeller has claimed that substantial improvement follows a more intensive course of graded exercises and occupational therapy in a rehabilitation centre, especially when combined with the administration of Bulgarian belladonna. Accordingly we decided to investigate the efficacy both of modern physical therapy and of drugs in this disorder. Our results in the limited number of cases which have come under our care encourage us to make a preliminary report on our investigations, which must of necessity take some years to complete.

Paralysis agitans is a syndrome in which certain changes in the mid-brain, affecting particularly some parts of the caudate nucleus and/or the substantia nigra, are present (Russell Brain, 1951). Cases may be divided into two principal groups. By far the larger is the degenerative group, in which the disease usually develops after the age of 50, but occasionally earlier; these may be further subdivided into a majority of idiopathic origin, and a minority, variously estimated as from 3 to 10%, secondary to arterial degenerative changes. The second main group comprises post-encephalitic cases, normally seen at a younger age. As is well known, in the majority of cases of paralysis agitans the patient's mask-like face and rigid movements often disguise sensitive feelings and mental clarity.

Material and Method

The present investigation covers 34 cases. Of these, 22 were considered to be of the idiopathic type, 3 were due to arterial degeneration, and in 9 there was a history of encephalitis. It must be recognized that in elderly patients in whom the disease has been present for many years precise differentiation may be impossible. The cases were unselected and came from the wards of chronic sick hospitals in East Kent; there were also a number of out-patients.

In these cases we have endeavoured, by means of drugs and by physical treatment consisting of individual and group exercises and occupational therapy, to rehabilitate the patients so that they may achieve the maximum degree of independence. As a preliminary patients were thoroughly investigated; they were assessed for mental capacity and graded according to

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whether they (A) possessed apparently normal capacity to respond intelligently; (B) showed a degree of impairment which did not render treatment impossible, but in which co-operation was difficult and only some relief of symptoms could be expected; or (C) showed little or no co-operation. Patients were also divided into three physical groups: Group 1, those who were reasonably mobile and had no undue rigidity or tremor; Group 2, those with a degree of disability—principally rigidity, which retarded remobilization; and Group 3, those in whom the disease was of long standing—generally with permanent physical changes, which precluded the possibility of remobilization.

Drugs

We have reviewed the extensive literature on the various drugs used in the treatment of paralysis agitans. While it has not been the primary object of this investigation to carry out a differential evaluation of these drugs, it has been found essential, in each case, to discover a drug or combination of drugs to relieve as much as possible the rigidity and salivation. No drug seems to be specific for tremor. The number of cases treated is too small to warrant conclusions being drawn, but our experience is recorded briefly.

The drugs used may be divided into three principal categories; and some others of importance are also referred to.

TRIHENXYPHENIDYL GROUP (including "Artane", "Kemedrin", and "Pipinol")

There is substantial support for the view that at present artane is the most useful drug, particularly in the treatment of post-encephalitic Parkinsonism (Efron and Denker, 1950). For this reason we have used this drug in all our cases. We confirm that it is of great value in post-encephalitic cases, and apart from transient giddiness there are few unpleasant side-reactions. It is not so well tolerated in the older age groups, and where there is mental deterioration it seems to accentuate depression, the patient often becoming confused. Restless patients tend to become excited and giddy. Seven of the 34 patients studied were unable to tolerate the drug. When artane is well tolerated it reduces rigidity and the change in facial expression is striking; it has much less effect on tremor and appears to have little effect in reducing salivation. Undoubtedly it is superior to the belladonna group of drugs in every respect except its effect on salivation, and it does not produce the dryness of mouth and changes of vision associated with those drugs.

In our series we started with a dose of 2 mg. thrice daily and increased this to 15 mg. daily, in one case up to 25 mg. We have found no advantage in the higher doses used by Garai (1951), as these tend to produce toxic symptoms, such as giddiness and confusion.

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ANTIHISTAMINE GROUP

"*Lysivane*."—This preparation was tested in New Zealand by Gallagher and Palmer (1950), who regard it as a drug of first choice. They used 500 mg. daily, and state that with this dose toxic effects are minimal, consisting only of occasional dryness of the mouth and diplopia. Garai (1951), however, found this drug appreciably more toxic than artane. Lysivane is probably the most important derivative of the antihistamine group in the treatment of paralysis agitans. We have used it in a few cases, but have not given more than 300 mg. daily. It seemed to be much less effective than artane, and for this reason we have not given it an extensive trial.

"*Benadryl*."—This is given as 50-mg. emplets four times a day and is strongly advocated by Moore (1951), who prefers to use it in combination with atropine. In our experience it is best used with artane, and we have found this combination (together with "rabellon" when there is troublesome sialorrhoea) to be the most effective, benadryl appearing to enhance the effect of artane. We have not used benadryl alone, and in this preference for a combination of drugs we agree with Edwards *et al.* (1951), who strongly advocate this form of therapy in Parkinsonism. We have found that a progressive build-up of several drugs is, in most cases, more effective than any single drug. Benadryl tends to cause drowsiness in some patients.

"*Diparcol*."—This drug is very prone to induce giddiness; nausea and vomiting, faintness, and agranulocytosis following its administration have been recorded. It is much less effective than artane in controlling rigidity, and most workers have discontinued its use (Garland, 1952). We have, however, found it valuable in one case.

Solanaceous Drugs.—Belladonna, hyoscine, and stramonium are the principal preparations in this group, and these have been given an extensive trial in the treatment of paralysis agitans. In general they are considerably less effective than artane in reducing rigidity, but are valuable in troublesome cases of sialorrhoea. Bulgarian belladonna has been advocated as superior to other forms of this drug, but recent work does not support this view. As stated above, we have used one of the drugs belonging to this group—rabellon—for the treatment of salivation. Hyoscine, because of its sedative action, may be effective in the treatment of tremor, the dose being 1/150 to 1/100 gr. twice or thrice a day.

OTHER DRUGS

"*Parpanit*."—This is given in doses of 12.5 mg. four times a day, increasing to five times a day. The first dose is then raised to 25 mg., and each succeeding day one of the remaining doses is similarly increased to the point of toleration. On an average, 50 mg. five times a day is well tolerated, and a dosage as high as 600 mg. daily may be possible (Bickerstaff, 1951).

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The chief side-effects are giddiness and light-headedness, to prevent which the drug should always be given on a full stomach. In two of our patients who could not tolerate artane a fairly good degree of control has been achieved with parpanit.

Amphetamine.—We have found this drug of great value in depressed patients and when benadryl is causing drowsiness.

Rehabilitation

PHYSICAL TREATMENT

If and when the mental state of the patient permits and he is able to co-operate at all we start physical treatment. We first endeavour to use assisted active movements and active exercises to reduce rigidity and improve co-ordination. It has been suggested that these patients do not respond well to group treatment, as they have a depressing effect on each other. We have found, on the contrary, that they respond very well to group exercises. Our experience has been that patients feel encouraged to find that they are able to take part in such activities again. We have noticed particularly the improvement in their mental alertness; we have also found exercises to music especially helpful.

Typical Example of a Table of Remedial Exercises taken by a Class of Patients Suffering from Parkinsonism

1. Sitting on a gymnasium stool: (a) hand and finger exercises to music, or (b) game using hands and arms, such as, "Do this, do that" (for mobilization and alertness).
2. Sitting on stool: knee and foot exercises such as (a) L. knee stretching with ankle plantar-flexing; (b) L. ankle dorsiflexing while knee is held straight; (c) L. ankle plantar-flexing; (d) L. knee and ankle bending to starting position. Repeat with R. leg. Repeat alternate legs, rhythmically to music.
3. Sitting on stool with trunk, arms, shoulders, and neck relaxed in stoop position: spine unrolling to erect sitting with arms by sides—to four counts. Sitting as erect as possible, arm-swinging sideways and upwards to tap shoulders and down; head rest and down; to ring position and down, and clap over head and down—to eight counts. Rhythmically to music.
4. Sitting on stool: rhythmical trunk bending from side to side, with or without music.
5. Standing (holding on to something firm with one hand such as wall bars): supporting leg braced as straight as possible, the other leg swinging from the hip, forward with straight knee, backward with straight knee, forward with slightly bent knee, and down to standing—to four counts. Repeat several times rhythmically to music, and then change to opposite leg.
6. Sitting on stool or lying: deep abdominal breathing, followed by relaxing exercises with eyes closed. (Patients are encouraged to do this every day at home, lying on a bed or sitting in an arm-chair with plenty of pillows.)

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Table of Remedial Exercises—continued

7. Standing astride: rhythmic arm-swinging exercise to music. With fingers and thumbs curled easily to touch, arm swinging forward to high reach position and downwards and slightly backward. Twice, to four counts.
Repeat forward swing and clap hands, looking upward—one count. Lower arms sideways and downwards with fingers stretched—three counts.
(Some patients have progressed to standing with feet together and later to heel-raising with the forward and upward swing of arms.)
8. Sitting on stool: trunk-rotation exercise (made up by one of the patients). Arms in punch position; (1) R. arm punch forward to reach position. (2, 3, 4) Trunk turning to left with arm held in reach position. (5, 6, 7) Trunk turning forward with arm held in reach position. (8) Right arm bending to starting position.
Repeat with L. arm and trunk turning to right.
9. Miming: either (a) individually, pretending to be bus conductors, drapers, fishermen, etc., or (b) in groups, miming a scene—e.g. something beginning with a certain letter—or a band or orchestra.
N.B.—All patients enjoy this and do not mind performing with others watching.
10. Stride standing, arm swinging across in front, then outward and upward to "V" position. Repeat—four counts. Then arm moving sideways, downwards, crossing in front and again over head, slowly to four counts.
Repeat the whole exercise several times, rhythmically to eight counts. To music, if possible.
(Patients are encouraged to stretch up and look up when arms are raised, and the more advanced patients have progressed to heel raising and lowering during the slow part.)
11. Standing (if necessary, holding on to something): L. heel tapping in front, L. toe tapping sideways, L. toe tapping backward, and then swinging L. leg forward—rhythmically to four counts.
Repeat several times, and then change to R. leg.
12. Walking re-education with or without music, working especially at the following points:
 - (a) Back and head held as erect as possible.
 - (b) Knee as straight as possible when the weight is on the leg.
 - (c) Heel down first and no shuffle.
 - (d) Correct use of feet with push-off from toe.
 - (e) Swing through from the hip.
 - (f) Arm-swinging. (With patients who find it difficult to swing the opposite arm to leg, poles are held in each hand and then the physio-therapist walks behind holding the other end of the poles and thus setting the swing. Several patients may walk between the poles and thus be helped in this way.)

N.B.—Variations of the above exercises have been taken. Sometimes the patients are given free practice for 10 to 15 minutes. They can use balls, rowing machines, static bicycles, shoulder wheels, gripping machines, slings and pulleys, walking bars, wall bars, etc. They are encouraged to change about and help each other. Dressing and undressing practices also are sometimes given and they are encouraged to be as independent as possible at home. Classes are taken for 30 minutes twice a week.

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Relaxation is of great importance. The patient, either sitting or lying, relaxes as completely as possible and breathes deeply with the eyes closed. Relaxation of the trunk associated with deep breathing helps to control tremor. Exercises to eradicate the typical shuffling gait, and also rhythmical exercises, are described in the Table of Remedial Exercises.

Some patients need a lot of encouragement to make the maximum effort of which they are capable. The very fact that effort is so troublesome because of rigidity tends to make them more and more inactive. Therefore steps must be taken to counteract inactivity, otherwise patients become increasingly less able to move. It is necessary that they should do such active exercises as are within their power, but they must avoid undue fatigue or any activity which increases their rigidity, because this will aggravate their anxiety.

OCCUPATIONAL THERAPY

Patients take well to occupational therapy, but they have difficulty with fine finger work, on account both of tremor and of slowness of movement. Forms of occupational therapy which involve the threading of needles should, therefore, be avoided. However, patients are well able to do basketry, stool-seating, and weaving and, in some cases, rug-making. Patients are progressively encouraged to find out how much they can do, and many rapidly become proficient.

Results have convinced us that on these lines a large number of patients can be rehabilitated to the point of being able to live in their own homes. Some can take up sheltered employment suited to their physical condition, and there is a marked increase in the degree of independence regained.

Results

In assessing results the following tests were used, as recommended by Schwab and Prichard (1951):

1. *Dynamometric Reading*.—A simple hand dynamometer is used to test grip in each hand. Loss of strength on the involved side is usual. Results are read in kilogrammes.

2. *Finger-Thumb Proximity Rate*.—Rate for a normal person, 5 per second. Those suffering from Parkinsonism are usually unable to attain a higher rate than 3 or 4 per second, and very often less.

3. *Circle Drawing*.—Patient, sitting in a comfortable position, is given a piece of paper and instructed to draw, with a pencil, ten circles over each other, with each hand.

4. *Chair Test*.—Rising from chair. Normal persons take half a second; those with Parkinsonism, 0.75 to 3 seconds.

5. *Handwriting Test*.—Patient writes his or her name, assessment being based on the handwriting.

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6. *Gait*.—Time taken to walk briskly along a measured 10-metre course. Normal person, approximately 5 seconds; Parkinsonian, 8 to 15 seconds.

In general, it may be said that there was very little sign of organic improvement. There was, however, definite improvement in performance owing to the greatly enhanced morale of the patients. The following cases are mentioned as examples.

The most striking improvement was observed in a woman aged 58, with the idiopathic type of paralysis agitans, who had been admitted to a chronic sick hospital, where she was in a depressed state. She was given artane, 6 mg. daily, with benadryl, 150 mg. daily, and improvement was immediately apparent. She could walk slowly and was able to help dress herself. She is now in a domestic situation, and quite able to carry out her duties, which include carrying trays containing meals.

Another patient, a man aged 32 with severe post-encephalitic Parkinsonism, who was very rigid and constantly tended to fall backwards when standing, has gained control of his walking. He was given artane, 25 mg. daily, and kemedrin, 50 mg. daily. He is active in occupational therapy, and has improved his performance to such an extent that we are seeking some sheltered employment for him.

A woman aged 38, with post-encephalitic Parkinsonism, an in-patient at a chronic sick hospital, was bent double when she walked and could not dress or feed herself. She was given artane, 8 mg. daily, and benadryl, 100 mg. daily. She now walks erect, is fully able to dress and feed herself, and is in other respects independent, though she is still in hospital.

In our experience the mental category of a patient does not change: if there is mental deterioration, it remains. The physical category does, however, improve, and some of the patients previously rated Group 3 are now in Group 2, and those originally in Group 2 are now in Group 1.

Of the 34 patients treated, 18 showed definite physical improvement as evidenced by their ability to dress themselves, by improved speed of performance in tests, and by increased dexterity at occupational therapy; one of them is now in regular employment, 4 are fit for sheltered employment, and 8 are domestically independent; the remainder still require some help. Details of the treatment of these 18 patients and of their progress are given in the table overleaf. Of the remaining 16 patients, 9 who have shown no improvement are all in mental category B or C. The other 7 patients, who were all advanced in age (71 to 85 years), have died.

The Effect of Injury

Injury, such as a fracture involving a limb, proves a serious handicap to these patients, as it causes a marked increase in the rigidity of the affected limb. It is very difficult, and sometimes impossible, to prevent deformity

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TABLE SHOWING PROGRESS OF 18 PATIENTS IMPROVED BY TREATMENT

Sex	Drug Treatment	Physical Condition		Mental Condition	
		At Start of Treatment	After 6 Months	Category Before Treatment	After 6 Months
M.	Artane not tolerated. Rabellon, 2 tablets thrice daily. Bulgarian belladonna, 15 mg. daily	Rigidity definite	Rigidity much less	B2	Much more alert and cheerful. B+
F.	Artane, 6 mg. daily. Benadryl, 150 mg. daily	Rigidity marked; tremor nil	Rigidity slight; very good general improvement	A2	Now capable of sheltered occupation. A1
F.	Artane, 12 mg. daily	Rigidity slight; tremor moderate	Rigidity little improved; tremor improved	A2	Improvement in morale and domestically independent. A1
F.	Artane, thephorin, and hyoscine	Rigidity and tremor very severe	Rigidity much less; tremor much improved	A3; post-encephalitic	Striking improvement in morale and physical condition
M.	Artane, 1 tablet thrice daily. Benadryl, 1 tablet thrice daily	Rigidity and tremor slight	Rigidity, little change; tremor, little change	A1; post-encephalitic	Slight general improvement. A1
F.	Artane, 6 mg. daily. Rabellon	Rigidity marked; tremor slight	Rigidity much less; almost no tremor	A2-3	General improvement. A2
F.	Artane not tolerated. Diparcol	Rigidity marked; tremor slight	Rigidity much less; tremor improved	A3	Handicapped by intracapsular fracture of left femur. A2
M.	Artane, 25 mg. daily. Histanin, 50 mg.	Rigidity very marked; tremor severe	Rigidity much improved; tremor much less	A2; post-encephalitic	Great improvement in co-operation and morale. A1
F.	Artane, hyoscine, phenegan, parpanit, and kemedrin	Rigidity and tremor marked	Rigidity varies; tremor less, but varies	A2; very unstable	Does not maintain progress; continually relapses. A2
F.	Artane, 12 mg. daily. Benadryl, 150 mg. daily	Rigidity marked; tremor slight	Rigidity much improved; tremor very slight	A2; dejected and neurotic	Striking improvement in morale. A1
M.	Artane, 6 mg. daily. Thephorin, 1 tablet thrice daily	Rigidity slight; tremor slight	Rigidity improved; tremor slight	A1; not severely handicapped	General improvement. A1
M.	Artane, 6 mg. daily. Thephorin, 1 tablet twice daily	Rigidity slight; tremor nil	Rigidity improved; tremor nil	A1; very static	Still very slow finger movements. A1
F.	Diparcol, 2 tablets thrice daily. Thephorin, 1 tablet thrice daily	Rigidity moderate; tremor severe	Rigidity slight; tremor much less	B2; mentally unstable	Now good morale; more stable. A1
F.	Artane, 1 tablet thrice daily. Benadryl, 1 tablet thrice daily	Rigidity slight; tremor slight	General improvement	A1	Much more cheerful. A1
F.	Artane, 1 tablet twice daily	Rigidity slight; tremor slight	General improvement	A1	Continued improvement. A1
F.	Artane, 400 mg. daily	Rigidity considerable; tremor definite	Rigidity and tremor slight	A2	General improvement. A1
M.	Artane, 24 mg. daily. Benadryl, 1 tablet twice daily. Hyoscine, 1 tablet (100 gr.) twice daily	Rigidity and tremor severe	Rigidity still severe; tremor improved	A2	Much more cheerful
F.	Artane, 12 mg. daily. Benadryl, 1 tablet twice daily	Very poor posture; post-encephalitic	Great improvement in posture	B2	Has made good progress with physical exercises

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and foot-drop in such circumstances. The application of plaster casts in cases of injury has proved of doubtful value, as the patients' joints readily become ankylosed.

In this series one patient had a fracture of the tibia into the knee-joint as a complication and another had an intracapsular fracture of the femur. In both cases the affected limb has been very rigid and in both we have had to fit a walking calliper. The patient with the fractured femur also had foot-drop, which needed correction.

Discussion

It is necessary first to emphasize that we are dealing with a small number of cases—34 in all. In 12 of these the patient was in a state of advanced physical and mental deterioration which precluded treatment other than that directed towards symptomatic relief. Nevertheless the improvement which has taken place in those patients whose physical and mental condition enabled us to treat them by a combination of individual and group exercises with modern drug therapy has been so striking that we are encouraged to suggest that this combined form of treatment deserves an extended trial, perhaps in a unit where more clinical material is available. From a review of the literature it appears that treatment by drugs is often overstressed and physical treatment undervalued. We wish particularly to emphasize the value both of exercises and group activities and of occupational therapy in these cases.

Three years ago McArdle reviewed the work being done in a German clinic where very optimistic claims were made for a three to six months' residential treatment with Bulgarian belladonna combined with intensive physiotherapy and occupational therapy. He found that there was a moderate and useful improvement in four patients out of seven; but none was cured. He gave it as his opinion that a combination of the newer drugs would be more effective than belladonna, and that the main asset of the clinic was the provision of daily active exercises and occupational therapy in an encouraging and enthusiastic atmosphere over a period of at least three months. Finally he states: "There may have been some confusion about what Voeller meant by 'cure'. There is, in my opinion, no doubt that his promises of improvement were far too optimistic."

This review of McArdle's accords very well with our own experience. In the present state of our knowledge it is not reasonable to speak of cure when dealing with a disease the majority of whose victims have degenerative changes in the midbrain. The post-encephalitic cases presumably have scarring as the result of an earlier acute inflammation, and possibly may not show further degeneration with adequate treatment.

Modern drug therapy appears to be a very definite advance on the older method of using solanaceous drugs. We can confirm that the artane group of drugs are the most useful when well tolerated. In our experience, how-

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ever, this is often not the case, especially where there is already some mental deterioration. We can also fully subscribe to what has been stated by a number of American workers, that artane gives better results when used in combination with other drugs. The combination of artane and benadryl appears to be most effective. We have added rabellon only in cases where salivation is present, and hyoscine when tremor is severe. It cannot be too strongly emphasized that there is as yet no ideal drug or treatment for this disease. It is necessary, by trial and error, to ascertain the optimum drug or combination of drugs for each individual patient, and no disease is more unpredictable in its course. With perseverance the most helpful drugs can be found for the patient, and when this is combined with adequate treatment by physical methods the improvement in his morale and mental outlook and in his performance is so marked that the progress of the disease appears to have been arrested. The tests which we have carried out do not appear to register any striking changes in the organic condition of the patients, but the cheerful and hopeful outlook engendered by the training they have received greatly helps to compensate them for their disability. It may be that the degenerative changes in the idiopathic cases of paralysis agitans have been arrested, but only time can show this. It is, perhaps, reasonable to hope that in the post-encephalitic cases, which are mostly in a younger age group, progressive improvement may take place.

Further work on this distressing syndrome would appear to be well worth while.

Summary

This investigation was undertaken to determine how far modern methods of physical treatment and drug therapy were effective in the rehabilitation of cases of paralysis agitans. The inquiry was particularly directed to 18 patients who were suitable for this form of combined therapy, all except one of whom showed appreciable improvement. Four were considered fit for light occupation in sheltered industry; 8 were fully independent in domestic employment; 2 were nearly independent but required some help; and 4 still required nursing attention. These last 4 patients are still in hospital, and the remainder are at home and attend as out-patients.

Of the drugs tested, artane was considered the most effective, but less so when used alone than when given in combination with benadryl. Rabelon, hyoscine, and amphetamine were added occasionally in suitable cases.

McArdle's report on the work of the clinic run by Voeller is briefly reviewed and commented upon.

More emphasis might well be placed on first-class physical treatment, and not so much, perhaps, on drug therapy, in the management of these cases.

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The results of this investigation were sufficiently encouraging to warrant further work on a larger number of cases. The great improvement in the morale of the patients is stressed.

Acknowledgments

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A POSTGRADUATE course in Physical Medicine will be held on Saturday mornings during October, November, December, and January. Classes will assemble at 10.15 a.m. at various London hospitals. The fee for the course will be two guineas.

It has also been agreed to hold a weekend course of lectures on Saturday and Sunday, January 30 and 31, 1954, at the London Hospital.

ELECTRIC DISPLACEMENT TRANSDUCERS FOR PHYSIOLOGICAL INVESTIGATIONS

By K. S. LION

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A TRANSDUCER is an apparatus which converts physical energy from one form into another. Thus an *electric* transducer may be used to convert light, temperature, or humidity, etc., into *electrical* energy or vice versa; for example, a photoelectric cell changes light into a variation of electric current or of resistance. The measurement of many physical changes in physiology, such as pressure or muscular force, is frequently made with the help of such transducers. Usually the physical magnitude to be measured is first converted into a physical displacement; for instance, a change in pressure is made to act upon a membrane and cause it to move, or a change in muscle tension alters the length of a spring. The problem is then to convert such physical displacements into analogous electrical forms. This stage is accomplished by means of *displacement transducers*, the output from which can be electrically measured, recorded, amplified, differentiated, or "processed" in any way the investigation demands. A simple example of such a transducer is the well-known phonograph pick-up, which converts the lateral or up-and-down movement of the stylus into corresponding electric voltages.

Characteristics of Displacement Transducers

The behaviour of a displacement transducer is in general characterized by seven factors. These are:

1. *The range of motion.* The displacements to be measured are usually small, ranging from less than one-tenth of a micron (<0.00001 cm. or order of $1/1,000,000$ inch) to several centimetres. This is an enormous range, and no single transducer is capable of covering it.

2. *The accuracy*—that is, the smallest displacement that can be measured within the specified range. Assuming, for instance, that a transducer furnishes one volt linear output for a total displacement of 5 mm., and that the associated equipment permits a measurement of the output voltage within ± 20 mV, then the smallest displacement that can be measured is 0.1 mm. or 2%, and this figure represents the accuracy of the system. The over-all accuracy is in fact usually limited by the accuracy and stability of the transducer and the associated equipment, by unavoidable statistical fluctuation (electrical noise), and by environmental influences (temperature, vibration, etc.).

3. *The force requirements.* Most transducers contain moving parts and require for their operation a certain amount of mechanical force to overcome friction or to act against restoring forces within the transducer. The

Electric Displacement Transducers

available forces involved in physiological experiments are in general of a low order (in contrast to most engineering applications of transducers), and low force requirements are essential for such applications as respiration measurements or plethysmography.

4. *The frequency range.* In general the displacements to be measured vary with time, and an ideal transducer would follow such variations over the entire range of velocities and frequencies of the displacements. In practice, however, this is never so, and an upper frequency limit is generally imposed by the mass of the moving parts, by resonance within the transducer and the system under investigation, or by the inertia of the physical process involved in the conversion of the mechanical displacement into the electric output. On the other hand, several types of transducer also exhibit a limitation of operation at low frequencies; to furnish a measurable output voltage these need a certain minimum velocity of the displacement.

5. *The output characteristics.* Some transducers furnish at their output terminals *voltages* analogous to the measured displacements; others produce a variation of *resistance* (or impedance) between the output terminals. However, the latter types, if used in connexion with the accessory equipment, will also furnish output voltages which vary as a function of the measured displacements. Both types can, therefore, be considered as "sources", and as such they are characterized by two magnitudes: (i) the output voltage level and (ii) the output impedance.

(i) The *output voltage level* of most transducers varies between a few microvolts and something in the order of 10 volts. Where the output from a transducer has the character of an A.C. voltage and where subsequent amplification is employed, low voltages even in the microvolt range will still furnish satisfactory results. Where the varying processes to be recorded are slow the transducer output has a D.C. character, and a level of at least 10 to 100 millivolts is desirable because of the difficulty of building satisfactory D.C. amplifiers for low input levels.

(ii) A high *output impedance* (resistance) limits the amount of power that can be drawn from a transducer, and also introduces difficulties when the transducer is remote from the rest of the associated electrical equipment (because of the capacitance of the connecting lines and of the possibility of external disturbance through electrostatic fields, both of which influences are much greater in connexion with high impedances). However, where at least the first amplifier tube can be mounted in close proximity to the transducer a high output impedance is not objectionable.

6. *The transfer characteristic.* The transfer characteristic is the functional relationship between the displacement and the resultant output of the transducer. This is a measure of the sensitivity of a transducer and the linearity or any deviation from linearity, such as hysteresis.

7. *The stability.* In general it is simple to build a transducer system of great sensitivity, but difficult to construct one that is stable, free of drift

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over long periods of operation, and uninfluenced by environmental changes, such as temperature variations, humidity, mechanical vibrations, or changes in supply voltages. Such factors are important for the satisfactory operation of transducers, but little material is available to allow of their quantitative evaluation, and apparently no comparative studies have been made of different transducer systems on the basis of stability.

These seven criteria describe fully the physical behaviour of a transducer. However, for the selection of a transducer it is frequently important to consider the requirements for the equipment associated with the transducer, its size and weight, the necessity for maintenance and—where economic questions are of importance—its cost. For instance, in the case of a resistance strain gauge transducer, the cost of the associated equipment surpasses that of the transducer by a factor of more than 100.

Types of Transducers

Reference to the many hundred publications on transducers allows one to distinguish the following classes: (1) resistive transducers; (2) capacitive transducers; (3) inductive transducers; (4) piezo-electric transducers; and (5) miscellaneous transducers.

1. RESISTIVE TRANSDUCERS

A. Slide-wire Transducers.—A resistance wire with a sliding contact which moves and varies a resistance corresponding to the displacement to be measured represents a very simple transducer. The most commonly used embodiment of this principle is the low-torque potentiometer, which consists of a wire-wound circular potentiometer body and a movable contact made of a special alloy. The torque needed for actuating such a transducer is in the order of 3/1000 ounce-inch (~ 200 dyne-cm.). The (angular) displacement range is in the order of 270° to 360° . The resistance between the movable contact and one end of the potentiometer does not increase continuously, but rather in steps caused by the length of resistance wire between two adjacent turns on the periphery of the potentiometer. This, of course, limits the accuracy obtainable. Through the use of very fine wire (1/1000 inch diameter) resolutions down to 0.2° can be obtained. The deviation from linearity can be made less than 0.1%. The stability is high, yet after long operation contact difficulties are likely to be encountered and the potentiometer tends to become "noisy". The circuit connected with such a transducer can be made ideally simple, a voltage source in the form of a storage cell being usually sufficient, and the output may be fed directly into a recorder.

The slide-wire transducer is best suited for applications where large angles of rotation are to be converted into analogous voltages and where slow variations of less than, say, 10 cycles per second are expected. It is, therefore, the logical choice for ergometers.

Electric Displacement Transducers

B. A particularly interesting form of a resistive transducer is the *spring transducer* (Wildhack and Perls, 1951). A spring is wound so that its stiffness increases uniformly along its length. It may be wound in the form of a helix or from wire of a uniformly increasing cross-section. The wire should preferably be gold-plated. When the spring is closed the single turns are in contact, and thus the resistance is small. When a force is applied which elongates the spring, the single windings become increasingly separated from each other, the current cannot pass direct from turn to turn, and thus the resistance increases. The range extends from a few hundredths of an inch to nearly one inch, and the variation of resistance from closed to the completely open spring varies from 1 : 20 to 1 : 50. The accuracy and the deviation from linearity are less than 1%. The spring transducer represents a very simple and elegant solution of the transducer problem, where the force requirements are tolerable. It is relatively new and has not as yet found applications in medical research. Dust particles collecting between the turns are likely to cause difficulties.

C. Numerous efforts have been made to build transducers based upon the *contact resistance* between semi-conductors (such as carbon), which varies with the applied pressure. The carbon microphone, based upon this principle, is probably the most widely used displacement transducer. However, the stability of the contact resistance, while sufficient for a microphone, is seldom adequate for measuring purposes. The relation between resistance and displacement is non-linear and shows hysteresis and erratic changes if there is a change in the number or location of the areas of contact between the carbon particles. The resistance also shows a large temperature coefficient. However, efforts to build transducers from carbon disks have been quite successful, and variations of resistance in the order of 50% for a displacement of 2/1000 inch have been reported, having an instability of not more than 1% over 18 months. The accuracy is in the order of 2% (McCollum and Peters, 1924).

Of some interest in this connexion are *carbon composition transducers*, usually in the form of finely divided graphite particles in a non-conducting matrix (shellac, plastic, resinous binders) (Rigden, 1942). Resistors of such compositions exhibit a variation of resistance when exposed to pressure. Such transducers generally have a small range of displacements (order of 1/1000 inch) and require considerable forces or pressures (order of 10 to 1,500 lb. per square inch). The relative change of resistance for the maximum load is about 1 to 5% of the total resistance. The accuracy obtained is about $\pm 5\%$ for static measurements and $\pm 2\%$ for dynamic measurements up to 50,000 c.p.s.

Contact resistance transducers have found applications in the measurement of force exercised by the teeth in biting.

D. The *wire strain gauge* has probably found the widest practical appli-

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cation of all resistive displacement transducers. This gauge consists, in principle, of an ordinary wire, fixed at one end and extended at the other. Such a wire shows a variation of resistance when stretched, resulting from the increase in its length, the decrease of its cross-section, and the variation of its resistivity under the influence of stress. The variation of resistance, in ohms, is $\Delta R = \lambda \cdot R \cdot dl/L$, where R is the resistance and L the active length of the wire, dl the displacement (the elongation of the wire under the influence of the acting force), and λ is the "gauge factor", a dimensionless figure which varies for different materials between $+3.5$ and -12.1 . For the frequently used "constantan" (cupro-nickel alloy) λ has the value of 2.0 . The practically obtained relative variation in resistance is in the order of 1% .

The wire is frequently arranged in zigzag form. It can be used without carrier (unbonded strain gauge) or cemented on an elastic backing (bonded strain gauge). The maximum range of displacement is usually of the order of $3/1000$ inch (~ 70 microns), and the accuracy better than 0.1% , limited only by the noise level or the resolution of the associated equipment. The forces needed to produce maximum output are between 1 and 50 oz. weight (30 to $1,500$ g. weight, or $30,000$ to $1,000,000$ dynes). The frequency range extends from zero to many thousands of cycles per second, although most practical forms have an upper frequency limit around several hundred cycles. The output impedance is in the order of several hundred ohms. The output voltage level depends upon the input voltage used to measure the resistance variation; for an input voltage of 10 volts one can expect an output voltage around 20 mV. The transfer characteristics are linear within about 1% (due to hysteresis and "creep" of the wire). The stability is very good; the strain gauge, however, exhibits a temperature coefficient of considerable magnitude, and the associated circuit has to provide for temperature compensation. Where strain gauges are used within an organism the temperature is usually stable enough to make such compensation unnecessary.

Much larger resistance variations can be obtained with *electrolytic transducers*, which consist generally of two electrodes in an electrolyte. The resistance of such a transducer is $R = \rho \cdot L/A$, where ρ is the resistivity, L the length of the liquid column between the electrodes, and A the cross-sectional area. By shifting the position of the electrodes, which requires only negligible forces, or by changing of A the resistance can be altered. The resistance can be measured with both D.C. and A.C. Also the electrolytic transducer has a temperature coefficient of about -2% per degree Centigrade.

Because it can be built very small, the electrolytic transducer lends itself readily to the measurement of intra-intestinal, intravenous, and intra-cardiac pressure.

Electric Displacement Transducers

2. CAPACITIVE TRANSDUCERS

Two advantages characterize the capacitance type transducer: (i) the extremely low force requirement to produce measurable capacitance changes, and (ii) the very high sensitivity with which capacitance variations can be measured.

The capacitance between two parallel plates, in mmf. (neglecting fringe effects), is $C = 0.224 \cdot \epsilon \cdot A/d$; it depends, therefore, upon ϵ , the dielectric constant of the medium between the two plates; A , the overlapping area in square inches; and d , the distance between the plates in inches. A variation of capacitance is usually brought about by the displacement of one plate and, therefore, by a variation of the distance by an amount Δd . The resulting capacitance variation is then $\Delta C = \Delta d \cdot 0.224 \cdot \epsilon \cdot A/d^2$, Δd being the displacement. Only for very small displacements is the capacitance variation proportional to the displacement; for large displacements the characteristics become non-linear, but can be partly corrected by the insertion of thin layers of materials with high dielectric constant (Brookes-Smith and Colls, 1935). A theory of a capacitive pressure transducer in which the moving electrode is a membrane (as used in physiological investigations) is given by Lilly, Legallais, and Cherry (1947).

The capacitive transducer can be adapted to almost any desired range. It is possible to measure displacements down to a small fraction of a micron (1/1,000,000 inch) with a sensitivity comparable to the one obtained with optical interference methods. Also the accuracy that can be obtained is high; Whiddington (1920, 1923) in his classical work on "Ultramicro-meters" has obtained resolutions of one part in a million. The high sensitivity of the method makes it possible to use electrodes and membranes with high natural frequencies, so that the frequency range covered extends from zero (static displacements) to beyond the audio-frequency range. The output level depends upon the circuit used, varying from microvolts to voltages in the 10-volt range. The output impedance is high, so that careful shielding, short connexions to the first input stage, and, at times, considerable experimental skill are needed. The stability of the capacitive transducer is largely determined by the stability of the associated circuit; considerable care is required to obtain freedom from drift over long periods of operation. Also, transducers of very high sensitivity are, of course, easily influenced by thermal expansions and similar effects.

Capacitance variations are measured best by radio-frequency methods—a fact which may be considered an advantage, since such frequencies are relatively simple to produce with stable and reliable electronic oscillators.

3. INDUCTIVE TRANSDUCERS

The general principle underlying these transducers is the measurable variation of an inductance brought about by a variation in physical dimensions. The inductance usually consists of a coil and a core of high

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magnetic permeability, and a simple transducer can be made by moving the iron core more or less deeply into the coil. More efficient is a system whereby the coil is arranged in a magnetic circuit with an air gap that can be varied by a moving member of high permeability, thus varying the magnetic resistance and, in consequence, the inductance of the coil. The mechanical restoring forces exercised by magnetic fields are usually several orders of magnitude higher than the forces exercised by electric fields in capacitive transducers; yet the magnetic transducers can handle a larger amount of power, so that the output impedances are smaller.

A considerable number of constructions and circuits have been proposed to convert translatoric or rotatoric motions into inductance variations.

Arrangements with single coils frequently create experimental difficulties, since the results are influenced by the frequency and magnitude of the applied voltage. Such methods can be improved by the use of two inductances, one fixed and the other variable, and by measurement of the ratio of both inductances with a ratio meter or with a bridge circuit. Further improvements can be obtained by arrangements in which the movement of the core (or of an intermediate coil) increases the inductance on one side and decreases it on the other (differential transformer). Inductive transducers of this kind can be built so small that they can be used for intracardiac pressure measurements.

An interesting modification of the inductive transducer principle is the *eddy current transducer*, in which the variation of inductance is brought about by a metal vane or a metal loop sliding into the magnetic field in front of a coil. Eddy currents arise in this vane; the vane therefore acts as a short-circuited secondary coil, and its effect is reflected back into the primary coil, reducing its inductance. The effect is particularly pronounced if radio-frequency currents are fed into the primary coil and used for the measurement of the inductance variation. The mechanical effect upon the vane is very small.

The *magneto elastic transducer* represents another variation of the inductive transducer. Certain materials, preferably iron-nickel alloys, show an alteration in their magnetic permeability under stress. This change of permeability can be made to cause a variation of an inductance, which furnishes a quantitative indication of the stress or of the applied force. The force requirements are high—at least several pounds.

Finally, there is a group of transducers in which the movement of a permanent magnet or of an electromagnet induces a voltage in a coil. Inasmuch as the magnitude of this voltage depends upon the time-variation of the magnetic field in the coil, these transducers furnish an output voltage which, *ceteris paribus*, is proportional to the velocity of the movement rather than to the displacement ("velocity transducer"). However, if the output from such a transducer is fed into an integrator (usually a resist-

Electric Displacement Transducers

ance-capacitance network), the integrator will show a voltage across its output terminals which is proportional to the displacement. This indirect method of displacement measurement is advantageous where vibrations or "noise" movements are superimposed to the displacement to be measured. The integration circuit reduces the noise level.

4. PIEZO-ELECTRIC TRANSDUCERS

The basis of such transducers is the piezo-electric effect occurring in crystalline quartz or in many other natural and artificial crystals, whereby these crystals, when exposed to stress in certain directions, develop charges on their surface which can be taken off by electrodes and measured with electrometers or vacuum-tube circuits. Piezo-electric transducers of the quartz type require considerable forces, and the voltage output levels are low (in the order of a few millivolts). However, through the use of a stack of thin strips of piezo-electric materials with flexible electrodes between them it is possible to obtain units which develop an output of one to several volts when a bending moment is applied. The ordinary phonograph crystal cartridge, which is generally built in such a way, is frequently a useful and inexpensive transducer for experimental purposes.

New artificial materials which show high piezo-electric effects have been developed in recent years and appear to be quite suitable for use in transducers. The *barium titanate transducer* is perhaps the most promising development for applications where the necessary forces are available and where only variational displacements are measured (no static displacements). A unit for acceleration measurements recently investigated (Fleming, 1951) at the National Bureau of Standards showed a resonance frequency of 80,000 cycles per second. The weight of the unit was 4 g. and the sensitivity 2 millivolts per "g" (unit of acceleration, 980 cm./sec.²). For such output voltages forces of several thousand dynes are required.

Piezo-electric transducers can be used advantageously as pickup elements for pulse-frequency or blood-pressure measurements.

5. MISCELLANEOUS TRANSDUCER SYSTEMS

Two more transducer systems may be of possible interest in connexion with medical or physiological research. The first of these uses an electronic valve whereby the position of the anode can be changed by means of a lever extending through the centre of an elastic membrane. Variation of this anode position changes the plate current. An embodiment of this principle is the RCA valve 5734. The total (angular) displacement range for this valve is $\pm 0.5^\circ$, for which the valve furnishes an output voltage of ± 20 V in a 75,000-ohm load resistor. The frequency range extends from zero to 12,000 c.p.s. The force or torque requirements for moving the lever are considerable. A similar system used for pressure measurement in the range from 0 to 30 inches Hg is described by Day (1949).

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The other system uses the physical properties of a high-frequency gas discharge (Lion, 1952). If a vessel filled with gas under reduced pressure and containing two electrodes is brought into the field of a high-frequency oscillator, a glow discharge will arise within the tube. If the external field is asymmetrical with respect to the two electrodes within the vessel, a D.C. voltage will be generated between these electrodes. The asymmetry of the field can be brought about by a wide variety of physical means, and the set-up can be used as a displacement transducer over a wide variety of ranges and output voltages. Ranges as wide as 6 inches have been covered; yet with other arrangements, ranges as small as 2 micro-inches. The accuracy can be made better than 0.1%, and the force requirements are negligible. Plate III shows a finger plethysmograph based upon this kind of transducer. A sensitivity in the order of 10 volts per mm. Hg can be obtained with this instrument.

Measurement of displacements is, of course, possible with a variety of indirect methods—for instance, by optical means, whereby the moving member varies the amount of light falling upon a photo-electric cell; or by thermal means, whereby the displacement causes a variation of convection from a heated wire. However, the tendency in experimental methodics seems to be more in favour of direct methods for the conversion of mechanical displacements into electrical signals.

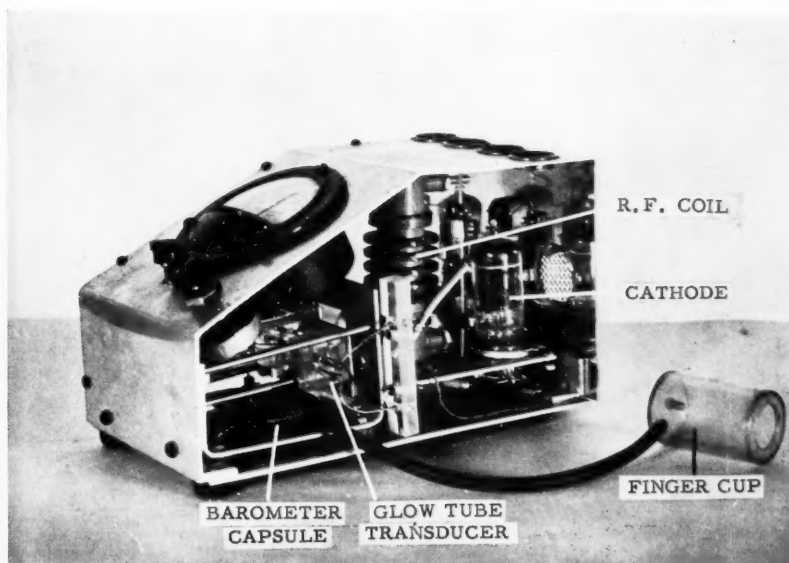
Summary

1. The mode of action of electric displacement transducers, which are used widely and to an increasing extent in physiological investigations to measure changes in blood pressure, muscle tension, etc., is described.
2. The characteristics of such transducers are discussed, and possible inaccuracies arising from their use emphasized.
3. A description of resistive, capacitive, inductive, and piezo-electric transducers is given, with examples of their application to physiological research.
4. The more recent moving anode valve and high-frequency gas discharge transducers are briefly discussed.

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PLATE III



Finger plethysmograph using glow-tube transducer. The pressure variation produced in the finger cup moves the membrane of a barometer capsule which, in turn, changes the field strength in the glow-tube transducer. The output from the transducer is led to a cathode follower and, from there, to a meter. An R.F. oscillator furnishes the supply voltage for the transducer.

K.S.L. face p. 306]

PLATE IV

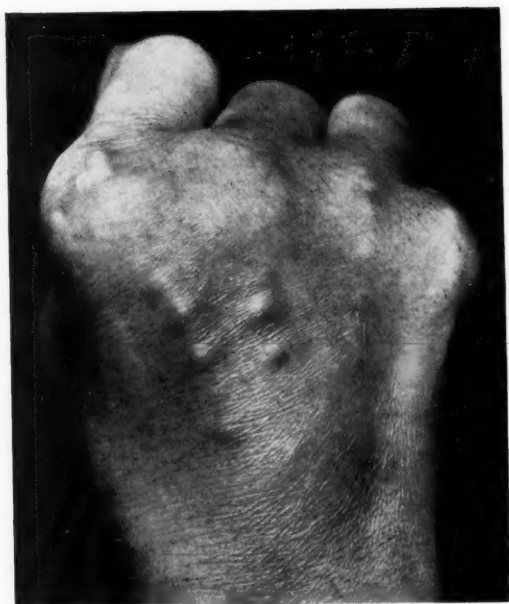


FIG. 1

Showing some of the nodules on the extensor tendons of the hands.

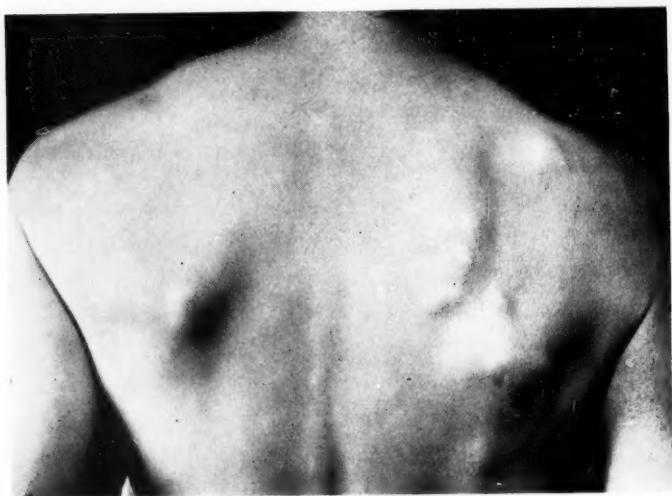


FIG. 2

Showing subcutaneous nodules near the right scapula.

CLINICAL REPORTS

A CASE OF NODULAR POLYTENDINITIS

TENDOVAGINITIS is a well-recognized clinical finding in some cases of rheumatoid arthritis, but the following case is unusual because of the widespread involvement of tendons by a nodular type of tendinitis which has caused no disability.

Case History

Clinical Features.—An unmarried woman machinist of 60 complained of pain, swelling, and stiffness of the hands, wrists, ankles, and feet, of insidious onset during December, 1950. She also noticed some pain and stiffness of the knees, elbows, and shoulders. Her general health was little affected, but the painful joints prevented her from following her occupation. During the next year the symptoms subsided in the larger joints, but the fingers, wrists, ankles, and feet remained painful and stiff with some residual swelling. A year after the onset she noticed the presence of nodules on the hands, forearms, and knees. These developed slowly, and she thought they tended to come and go over periods of several months. The nodules caused no discomfort or disability and appeared to be unrelated to the pain. Her previous health had been good except for attacks of pharyngitis, and she had been free of these for three years before the onset of the arthritis. She has one sister, who has rheumatoid arthritis but who has noticed no nodules.

The striking feature on examination was the remarkable appearance of the superficial tendons of the hands and wrists. These were studded with nodules 3 to 4 mm. in diameter and spaced at like intervals (Plate IV, Fig. 1). The nodules were best seen on the extensors of the fingers and thumbs, on the tendons of flexor carpi ulnaris, flexor carpi radialis, and palmaris longus. There was no evidence of similar nodules on the flexor tendons of the fingers and thumbs, nor on the tendons of the feet.

Further examination revealed a woman in good general health with typical rheumatoid arthritis of the wrists, fingers, ankles, and feet. The range of movement of the affected joints was moderately restricted, and there were capsular thickening and tenderness. Although still active, the disease was of a mild, chronic type. A large number of subcutaneous nodules was also present. Many of these, 1 or 2 cm. in diameter, were to be found over both scapulae, particularly the right (Plate IV, Fig. 2). Some were attached to the scapular spine and some to the deep fascia; some were embedded in muscles, while others lay in the subcutaneous tissues. One nodule was cystic; none was attached to skin. In the elbow region small nodules, 3 to 4 mm. in diameter, were present over the external epicondyles of the humerus and the upper end of the ulna. There were a few more of a similar size around both patellae. The other systems were normal.

Investigations.—Radiological examination of the hands, wrists, and feet revealed a moderate degree of generalized osteoporosis. Juxta-articular osteo-

Clinical Reports

porosis was seen in the hands. There was little evidence of cartilage destruction or marginal erosion except in the wrists. There was no calcification in the nodules. The haemoglobin percentage was 82 (Haldane), and the erythrocyte sedimentation rate 28 mm. in one hour (Wintrobe) after correction for the mild anaemia. The serum uric acid and calcium levels and the plasma phosphorus and alkaline phosphatase levels were all within normal limits. The serum cholesterol level was slightly raised at 257 mg. per 100 ml. Biopsy of a tendon was contemplated, but was considered unjustifiable in the circumstances. The patient has now been under observation for two years without appreciable change having occurred in either the nodules or the joints.

Comment

The tendon lesions of rheumatoid arthritis may take the form of a polytendovaginitis which, in rare cases, may occur without joint involvement (Sperling, 1950, who also quotes a paper by Baumgartner); or of tendovaginitis of the flexors of the fingers causing snapping finger (Helweg, quoted by Kellgren and Ball, 1950) or limitation of active flexion (Kellgren and Ball, 1950) and rupture (Harris, 1951). The case here reported is unusual in that there is no disability although the nodules are widespread on the tendons, the condition being a nodular polytendinitis instead of the more usual tendovaginitis. This type of widespread nodular lesion, although mentioned by Sperling (1950), seems to be rare, since the present case is the only one found among 544 cases of rheumatoid arthritis seen in this department since January, 1949.

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PLATE V

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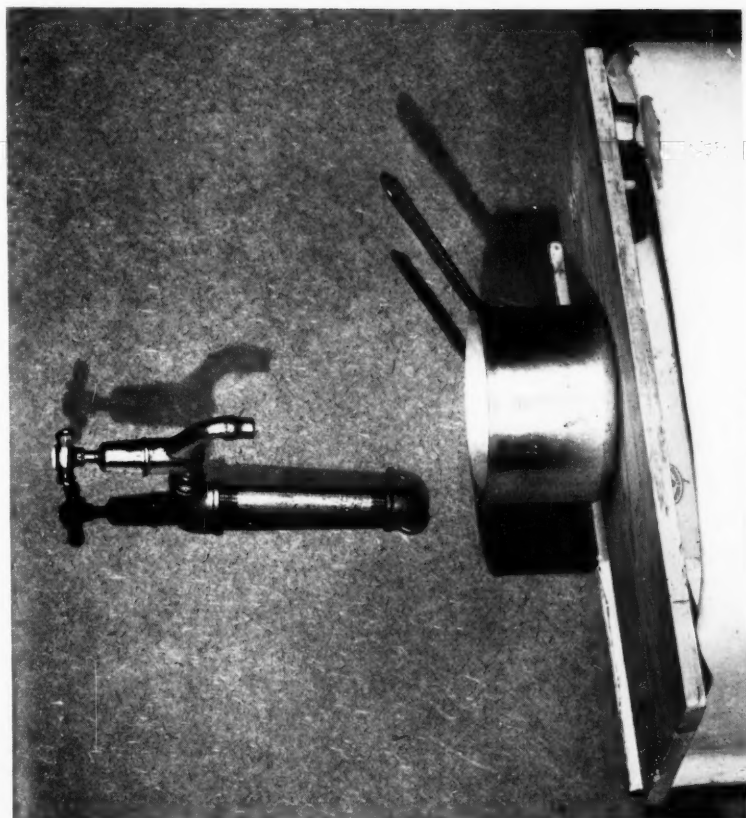


FIG. 1
To show board and saucepan in position on sink. Tap fitted with extension.

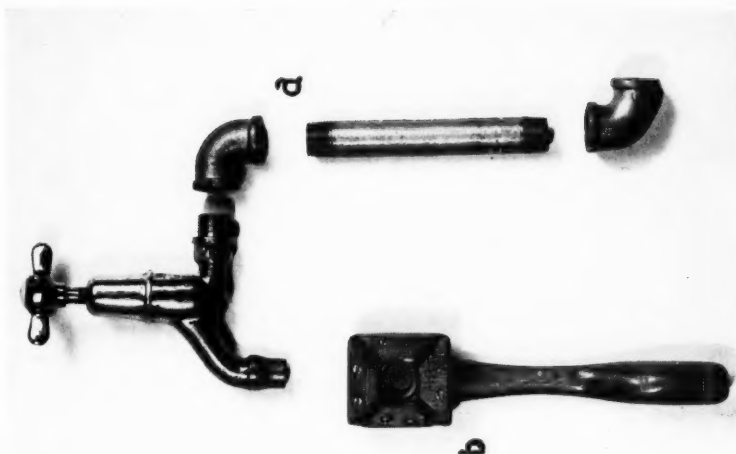
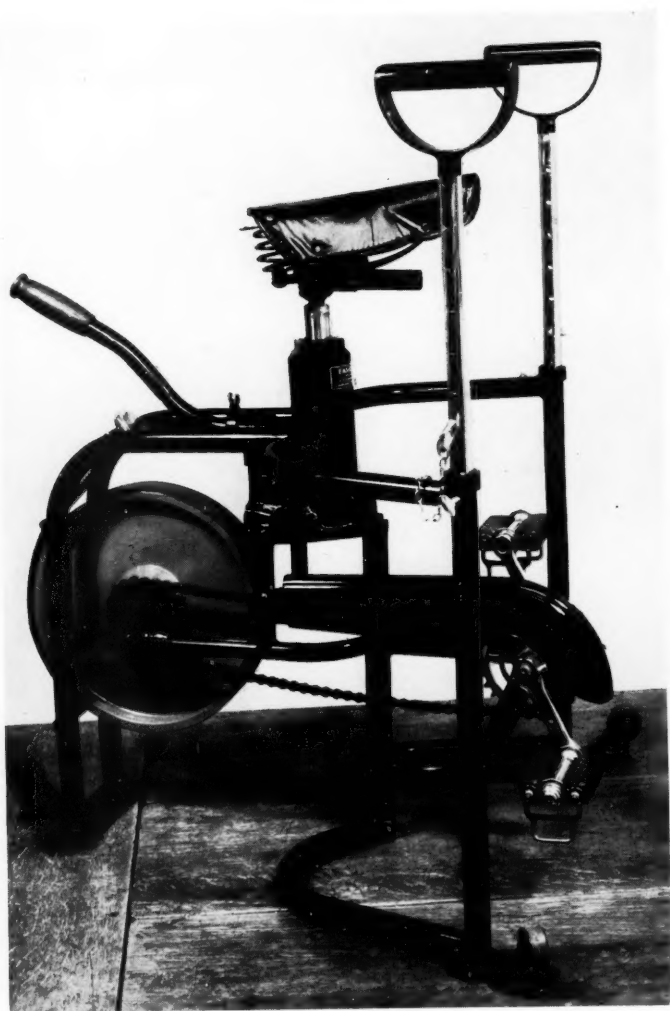


FIG. 2
a. Extension dismantled. *b.* Wooden key for turning tap.

PLATE VI



St. Benedict's static cycle.

[N.S.C. face p. 309]

NEW APPLIANCES

AIDS TO THE USE OF KITCHEN TAPS

A HOUSEWIFE with weakness of grip, when attempting to fill a saucepan or kettle with water, finds difficulty in turning the tap, holding the vessel while it fills, and carrying it to the cooker when filled. The ideal method of overcoming these difficulties is that described by Cooksey in the *Annals* for October, 1952, in which the kitchen is replanned so that all working surfaces are at the same level and interconnected, the sink being fitted with a mixing tap with lever handles and a swinging delivery pipe. A number of patients are, however, unable to afford this installation, and the arrangements described below have been developed to meet the demand for something cheaper.

The tap (Plate V, Fig. 1) may be turned by means of the wooden key illustrated in Fig. 2*b*, which consists of a piece of hardwood recessed at one end to fit the handle of the tap, the other end being shaped as a lever, the length depending on the leverage required. While being filled the vessels are supported on a board fitted with battens underneath to hold it in place across the sink. They may then be transferred to the cooker, either on an inclined plane if the cooker is adjacent to the sink, or by means of a simple trolley, as described by Cooksey, if the cooker is some distance away. To enable vessels to fit under the tap when the board is in position it is often necessary to raise the tap several inches. This can most easily be done by fitting the extension illustrated in Fig. 2*a*, which can be made and fitted by any plumber for a small sum, and consists of a length of water piping of suitable diameter, threaded to fit a right-angled section at each end, one of which is attached to the water-pipe, the other to the tap.

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ST. BENEDICT'S STATIC CYCLE

THE machine illustrated in Plate VI is a complete breakaway from the standard type of static cycle. It can be used by any patient, whether adult or child, lying down or sitting up. There are no handlebars to prevent the patient getting on to the saddle, which is raised to the required height by means of a hydraulic jack after the patient is seated. It can be pedalled from the normal position, from a chair facing the cycle, or from the side of the bed, and is rendered portable by hinged castors.

The model illustrated is available from Standard Sales, Ltd., 113 Newington Causeway, London, S.E.1, and costs £32.

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ABSTRACTS OF THE LITERATURE

Our Experiences with Hormonal Therapy in Chronic Rheumatic Diseases and its Hidden Dangers. F. LENOCH and J. KNOBOVA. *Věstn. čsl. fysiat. Spol.*, 1952, 30, 196.

This discussion is based on the results of treatment in 21 patients. The authors believe a physician irresponsible who will promise a patient in the fourth stage of rheumatoid arthritis a "dramatic or miraculous success" with steroids. The following is taken from their summary:

"Cortisone and ACTH do not cure anything, and at best bring about temporary and frequently complete remission during the period of administration. The more advanced the disease, the less pronounced the remission. Cecil's point of view is negatively exaggerated, whereas the reports of most other authors are too optimistic. Rheumatic diseases are not caused by adrenal cortex dysfunction, for neither rheumatoid nor ankylosing spondylitis is seen in Addison's disease. Thus cortisone is not a replacement therapy. These steroids are very interesting biologically, but from the therapeutic point of view they offer only the advantage of facilitating rehabilitation of rheumatoid patients. Treatment with these hormones requires close supervision for at least the first month, for the side-effects may be sudden and severe. Exceptionally there is a paradoxical response to therapy."

SIDNEY LIGHT

The Use of More Potent Cobra Venom for Intractable Pain. R. G. HILLS and W. M. FIROR. *Amer. Surg.*, 1952, 18, 875.

Cobra venom is considered by the authors to be an excellent analgesic agent which is relatively non-toxic and not habit-forming. They believe that this drug has not been widely accepted in the past because of (1) inadequate dosage, (2) the presence of a haemolytic factor, and (3) the failure to recognize the latent period. The analgesic effect of cobra venom is obtained only after many repeated injections, usually within a period of twenty days, but thirty days may be needed for results to appear. Once effective levels of the drug are secured, they can be maintained with minimal quantities.

Cobra venom was used by the authors to control pain in patients with inoperable malignant disease. Gratifying results were also obtained in patients with severe migrainous headaches. The authors' experience would indicate that 50 mouse units of cobra venom can be safely given subcutaneously twice a day for an indefinite period. As the drug has a cumulative action, after the maximum effect has been secured the dosage can be reduced to one injection every other day or every third day. Excessive quantities may cause transient diplopia and hemiplegia.

[The abstracter has had beneficial results from the use of cobra venom in the above-suggested doses to control pain in skeleto-muscular disorders, particularly in the so-called "frozen shoulder" syndrome. He considers that cobra venom should be more thoroughly evaluated in the treatment of painful chronic conditions of the locomotor system.]

O. F. VON WERSSOWETZ

Abstracts of the Literature

Disabled Men Work Again. S. L. HANSON. *Amer. J. publ. Hlth*, 1952, **42**, 787.

The author describes the work of the Liberty Mutual Insurance Company, of Boston, Massachusetts, which organization, as "a leading writer of compensation coverages", is closely concerned with all problems of industrial disablement. The company founded rehabilitation centres because of the tragedy of serious disablement and the high cost of compensation. The services provided included physiotherapy, occupational therapy, and recreational therapy five days a week, together with vocational guidance and pre-training courses. Rehabilitation nurses looked after the patients' interests throughout the period of rehabilitation; they called on the patient in hospital, they supervised his training, placement, and follow-up, and the co-ordination of the whole programme of rehabilitation.

In the last ten years 2,000 cases have passed through their hands; two-thirds of the patients have returned to productive employment. Of 200 patients with a major amputation, three-quarters have returned to some form of employment.

C. B. WYNN-PARRY

Physical Medicine in Office Treatment. A. L. WATKINS. *Med. Clin. N. Amer.*, 1952, **36**, 1485.

The author states that the conditions which are amenable to physical treatment in the doctor's surgery include poor posture, degenerative joint disease, rheumatoid arthritis, hemiplegia, multiple sclerosis, combined systemic diseases, and Parkinsonism. He also discusses "a condition usually known as fibrositis, which to those in physical medicine is a distinct entity on careful manual examination. These patients are found to have localized areas of muscle spasm which feel like nodules, which are quite tender to pressure but are favourably influenced by rather deep massage (kneading), which very often miraculously relieves severe pain and muscle spasm. Local application of heat before or after massage is usually indicated, as is head traction sometimes, particularly where there is an element of poor postural neck alignment. Therapeutic exercises may be of value in the prevention of recurrent attacks by improving musculature of the upper back and neck and teaching proper habits of postural alignment."

SIDNEY LICHT

Analysis of Muscle Action Potentials as a Diagnostic Aid in Neuro-muscular Disorders. F. BUCHTHAL and P. PINELLI. *Acta med. scand.*, 1952, **142**, 315.

In this paper is described a study of the durations, forms, and amplitudes of motor unit action potentials in normal muscles and atrophic muscles resulting from myopathic and neuropathic lesions. The authors refer to monopolar, concentric, and bipolar electrodes and the distortions that may result from their use. It is noteworthy that they describe the concentric needle electrodes as the ones causing the least distortion of potential changes. They relate this to the relatively low impedance of such an electrode, compared with the input impedance of the type of amplifier used in electromyography.

Of particular interest is their reference to the detection of motor unit action potentials of normal or increased duration and increased amplitude in muscular

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dystrophies. They discuss this finding at length. They confirm that motor unit potentials of increased duration occur in lesions of neurogenic origin—a finding particularly constant in those of spinal origin. They also report that in atrophy of spinal origin the increase in duration is generally accompanied by increase in amplitude, while in that of peripheral origin the opposite is found.

A. T. RICHARDSON

An Objective Method of Evaluating Muscle Tightness. W. LAJOIE and J. GERSTEN.
Arch. phys. Med., 1952, 33, 595.

In an attempt to evaluate muscle tightness the authors decided to use the spastic elbow flexors of hemiplegics. The forearm of the seated patient was strapped to a board which pivoted at a point corresponding to the position of the elbow. Increasing resistance was given to the elbow until an extension of 1.5 degrees was produced from an angle of 145 degrees. With this value as the baseline, several procedures were tested: hot packs, hot wax baths, tetanizing current, galvanic current, ethyl chloride spray, mephanesin, and infra-red irradiation. Only the last two agents reduced spasm.

SIDNEY LIGHT

BOOK REVIEWS

Galvani: a Translation of Luigi Galvani's "De Viribus Electricitatis in Motu Musculari Commentarius." By ROBERT MONTRAVILLE GREEN, M.D.
Published at Boston, Mass., by Elizabeth Licht. \$4.00.

Although some observations on electrically provoked muscle contractions had previously been made, no attempt at systematic investigation into this phenomenon was attempted until Galvani, towards the end of the eighteenth century, began his experimental work on animal electricity. In this way he laid the foundation of electrophysiology and its subsequent clinical application to electrodiagnosis.

In this small book of just under 100 pages is presented the first English translation from the Latin of Galvani's own records of experiments in this field. This interesting historical document is preceded by an introduction by Dr. Giulio C. Pupilli, Director of the Institute of Human Physiology of the University of Bologna, and a dissertation by Giovanni Aldini, a nephew of Galvani.

The section devoted to the translation of Galvani's commentary is divided into three parts. The first relates how frog preparations were noted to react by muscular contractions when the spinal nerves were touched with a metallic conductor in the neighbourhood of spark discharges. The second describes experiments carried out on similar preparations but making use of atmospheric electricity. The third deals with the experiments with the bimetallic arc, which more directly relates to the term "galvanism". Unfortunately, the book covers only the period when Galvani erroneously supposed that he was liberating animal electricity by means of metallic arcs, and not the more important period when he did indeed demonstrate the existence of electricity intrinsically of animal origin. Although the two letters which conclude the book touch on his differences with

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Volta, they are of too early a date to put into its proper perspective the controversy which raged concerning the opposing views of these two great men, and which proved so fruitful to science both in physics and electrophysiology.

The style of the translation, which conveys the impression that an effort has been made to evoke the flowery mode of expression prevalent in Italy in Galvani's day, tends to blur the objective and to make reading somewhat tedious; indeed, some long sentences are so ornate and so involved as to be well-nigh incomprehensible. Dr. Pupilli's introductory remarks go a long way towards making subsequent reading understandable.

The reviewer, while fully agreeing with Dr. Licht that Galvani's contribution to electrophysiology should be made available in English, feels that some readers will share his disappointment that the more important of Galvani's later observations which led to the concepts of rest, injury, and action potentials have been omitted.

The book, which contains copies of four delightful original illustrations, is well produced, and should prove of the greatest interest to students of those branches of medicine which straddle physiology and physics.

P. BAUWENS

Disc Lesions. By JAMES CYRIAX, M.D. London: Cassell & Co. Pp. 37. 5s.

One of the duties of a reviewer is to tell his readers what a book is about. Certainly if the review is signed it is his privilege to comment on the work and its presentation.

This book contains thirty-seven pages. The main headings are: Theory; History; Examination of the Spine; Root Pressure; Treatment of Disc Lesions; Treatment of Thoracic Disc Lesions; Treatment of Lumbar Disc Lesions; and Osteopathy. There is a short foreword by a disciple who is in general practice, and a preface written in French from an address in Paris by another disciple.

The great masters of clinical teaching such as Lord Horder have been able to give simple and clear clinical pictures which have been of permanent value to their students. Simple didactic statements are, however, not always a digest of knowledge gained from long clinical experience. In the seventeenth and eighteenth centuries it was not unusual for people to proclaim their wares—political, social, or financial, and even medical—to the public in the form of signed pamphlets. Dr. Cyriax seems to have adopted this method: in this book he proclaims what to him undoubtedly are facts.

He claims that disk lesions are easy to recognize; also that the physiotherapist should manipulate the patient's spine on the advice of the general practitioner, and that if the general practitioner is not too busy he should do this himself. Useful diagnostic and therapeutic tips are given. Undoubtedly, many patients treated in this way will get better, but others will not be suffering from disk lesions as recognized by the neurologist, orthopaedic surgeon, and specialist in physical medicine. Unfortunately, your reviewer has, during the last two weeks, seen two patients sent to him with so-called "disk lesions"—patients "ripe" for manipulation by the practitioner, who has neither the knowledge nor the facilities to make a proper differential diagnosis. One of these patients was found to be suffering from a localized lesion of a multiple myelomatosis, and the other from a tumour of the spinal cord.

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The question that he puts in his paragraph on osteopathy is, "Physiotherapists or Lay Manipulators?" This is not a proper question because the training of the physiotherapist is, and should be, concerned mainly with technique and not with diagnosis. Physiotherapists, however intelligent and enthusiastic, are not competent to diagnose disk lesions.

Without doubt Dr. Cyriax is a clever man and an enthusiast, and has much to give to his patients, his colleagues, and his physiotherapists. However, this book is a dangerous one and, if his enthusiasm will allow him time to pause and think, almost certainly he would be the first to recognize this.

FRANCIS BACH

The Prenatal Origin of Behavior. By DAVENPORT HOOKER. Lawrence, Kansas: University of Kansas Press. Pp. 143. \$2.50.

Human Locomotion and Body Form. By DUDLEY J. MORTON and DUDLEY DEAN FULLER. Baltimore: Williams and Wilkins Company. Pp. 285. \$5.00.

Davenport Hooker has been studying foetal activity in the human being since 1932, mostly at the University of Pittsburgh. In *The Prenatal Origin of Behavior* he summarizes the results of these studies as well as those of other outstanding workers in the same field. The book, which is based on a lecture delivered at the University of Kansas, is an excellent recapitulation of the work of the author, as well as of the unusual studies of George E. Coghill which preceded it. It is more than a summary of experimental work: it is a successful attempt at integration of the material. In the controversy over Coghill's thesis that reflex mass movements precede individual reflex movements in the foetus, and Windle's contention that the opposite is true, Hooker takes sides with Coghill in a manner which is convincing, and his deduction from the available evidence that the behaviour of vertebrate animals can be traced step by step from the foetal to postnatal behaviour reflects the ability of the man to go beyond the mere data of his observations.

Human Locomotion and Body Form is an extension of Morton's earlier study on *The Human Foot*, published in 1935, and shows a breadth of conception which is stimulating. Its emphasis on the development of human movement characteristics is mostly phylogenetic. It not only contributes to an over-all understanding, but offers many new and stimulating concepts. Although it is far from a complete study on locomotion, it is certainly comprehensive on the mechanical aspects. Morton's special interest in the foot exhibited in his earlier volume is again evident in this contribution. There is an interesting chapter on genetic considerations in which the complete rejection by the formal geneticists of the theory of the inheritance of acquired characteristics is questioned. The ideas expounded are those of the Neo-Lamarckians, but it must be confessed that they are sufficiently cogent to stimulate latent doubts about sole reliance on genetic mutations for variations.

These two books, with two phases of movement for their subject-matter, certainly have integrated their authors' individual spheres of interest, and it is to be hoped that they will stimulate further thinking on the over-all problems of human locomotion.

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